CEBAF Program Advisory Committee Nine
Extension and Update Cover Sheet

This update must be received by close of business on Thursday, December 1, 1994 at:

CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

Experiment: E 94 - 015

Check Applicable Boxes:

☐ Extension ☐ Update ☒ Hall B Update

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PAC9 UPDATE FOR CEBAF EXPERIMENT 94-015

Study of the Axial Anomaly using the $\gamma\pi^+ \to \pi^+\pi^-$ Reaction Near Threshold

Contact person: R. A. Miskimen

It has been widely noted that the QCD Lagrangian is easy to write down but difficult to solve. For this reason Weinberg suggested the development of effective Lagrangians based on the full symmetries of QCD. In the limit of massless quarks QCD has an exact $SU(3)_L \times SU(3)_R$ symmetry, which is dynamically broken resulting in eight Goldstone bosons (π, K, and η). The simplest $O(p^4)$ effective Lagrangian which includes the pseudo-scalar mesons has, without external fields, the symmetry $\mathcal{L}^{(4)}_{eff} \to \mathcal{L}^{(4)}_{eff}$ under $U \to U^+$ where $U = exp(i\vec{\lambda}\cdot\vec{\pi}/F_\pi)$, $\vec{\lambda}$ are the eight Gell-Mann matrices, and $\vec{\pi}$ the eight pseudo-scalar meson fields. As noted by Witten, this symmetry is not a symmetry of QCD and would forbide the transition $K^+K^- \to \pi^+\pi^0\pi^-$. This discrepancy is an "anomaly", where a symmetry of the classical action is not shared by the full quantum theory. Historically the chiral anomaly was first discovered by Adler, Bell, Jackiw, and Bardeen in the context of π^0 decay. Later Wess, Zumino, and Witten systematically constructed an anomalous $O(p^4)$ Lagrangian with negative parity under $U \to U^+$. This experiment will measure the amplitude for $\gamma \to 3\pi$ which is predicted by the WZW Lagrangian.

Since this proposal was accepted by PAC 8 in June of this year, several theoretical developments have occured. d'Hoker and Weinberg recently proved the uniqueness of the WZW Lagrangian (see S. Weinberg in "Proceedings of the M.I.T. Workshop on Chiral Dynamics", Cambridge MA, July 1994, to be published). Therefore, no other formulation of the anomalous action is possible and the results are model independent.

Holstein and P. Venugopal, a UMass graduate student, are working on calculations of the chiral anomaly. They plan to calculate the amplitude for $(\pi^+\pi^-)_{atom} \to \pi^0\gamma$ which provides a measure of the $\gamma \to 3\pi$ vertex. While the $O(p^4)$ contribution to $\gamma \to 3\pi$ is given by $\mathcal{L}_{anom}$, at non-zero values of momentum transfer squared it is important to include non-anomalous contributions at order $O(p^6)$ and higher. These terms will be modeled through the Hidden Gauge Symmetry model with the inclusion of vector meson contributions. Using the same theoretical framework they also plan calculations of $\eta \to \pi^+\pi^-\gamma$, which is sensitive to the anomaly. We plan to determine if $\eta \to \pi^+\pi^-\gamma$ could be measured concurrently with our $\gamma p \to \pi^+\pi^0 n$ experiment.

In extracting the $\gamma \to 3\pi$ amplitude from $\gamma p \to \pi^+\pi^0 n$ data, background reactions such as $\gamma p \to \pi\Delta$ may the limiting factor. For this reason we are interested in calculations of $\gamma p \to \pi^+\pi^0 n$ in the low t region that include the chiral anomaly and πN^* resonance backgrounds. We have formed a collaboration with M. Benmerrouche at Saskatoon and M. Kennedy, a theory student at the Univ. of New Hampshire, to work on these calculations.

In a parallel effort, we have made contact with A. Bolokhov at Leningrad State Univ. on the problem of obtaining $\gamma\pi^+ \rightarrow \pi^+\pi^0$ cross sections from $\gamma p \rightarrow \pi^+\pi^0 n$ data. This problem is related to that of obtaining $\pi\pi$ scattering cross sections from $\pi p \rightarrow \pi\pi N$ data. Bolokhov and his collegues have developed a model independent analysis for the pion data based on a Chew-Low extrapolation technique in the physical region, where extrapolation to the physical pion pole isn't required (A. Bolokhov, *et al.*, Nucl. Phys. **A530**, 660 (1991)). We are investigating if the theoretical machinery developed for $\pi\pi$ scattering can be applied to our problem.

Regarding experimental preparations, the three co-spokespersons for the experiment (R. Miskimen, K. Wang, and A. Yegneswaran) are actively involved in the development and construction of CLAS. R. Miskimen recently spent a sabbatical year at CEBAF where he spent much of his time working on the design of the chamber mounted electronics for the CLAS region 1 drift chamber. Since returning to UMass he is continuing to work on this project with the assistance of several students. K. Wang recently moved to the University of Virginia where he is working on the development of a linearly polarized photon source for CLAS. A. Yegneswaran, as a CEBAF staff member, is on site 100% of the time and is responsible for the CLAS drift chamber electronics.

Linearly polarized photons can aid in the identification of pseudo-scalar exchange mechanisms through the $(1 - cos2\phi)$ azimuthal dependence of the cross section. Other reaction mechanisms, such as $\gamma p \rightarrow \pi\Delta$, will not in general have this angular distribution. K. Wang is working on the development of a source of linearly polarized photons for CLAS for this and other experiments, and we plan to submit an extension of the experiment to linearly polarized photons at a future PAC.

The $\gamma 1$ Running Period at CLAS

December, 1994

The CLAS running period entitled $\gamma 1$ (Gamma 1) presently consists of those experiments which use a liquid hydrogen target and the real photon tagger. The running requirements of the experiments are overlapping and will be outlined here. The experiments are:

- 89-004 Electromagnetic Production of Hyperons (Schumacher *et al*)
- 89-024 Radiative Decays of the Low-Lying Hyperons (Mutchler *et al*)
- 91-008 Photoproduction of η and η' Mesons (Ritchie *et al*)
- 93-033 Search for Missing Baryons Formed in $\gamma p \rightarrow p\pi^+\pi^-$ Using the CLAS at CEBAF (Napolitano *et al*)
- 94-015 Study of the Axial Anomaly Using the $\gamma\pi^+ \rightarrow \pi^+\pi^o$ Reaction Near Threshold (Miskimen, Wang, Yegneswaran *et al*)

As can be seen from the titles, the range of physics addressed by these experiments is broad. Two involve the production and decay of strange particles, one seeks to determine the presently unknown eta photoproduction cross sections, while the others exploit the relative simplicity of photoproduction to probe poorly known sectors of hadronic physics. E89-004 will explore the photoproduction of the ground state hyperons Λ, Σ^o and Σ^+, adding abundant polarization data available for the first time. This will make it possible to extract several hadronic couplings and definitively describe the resonance structure of these reactions. E89-034 will use CLAS as a copious source of excited hyperons, such as the $\Lambda(1405)$, and extract the small radiative decay branching ratios by reconstruction of the hadronic decay products. These provide particularly sensitive tests of quark model structure of the hyperons. E91-008 plans to measure the differential cross sections for η and η' photoproduction using detection of the recoil protons in CLAS. These measurements are viewed as providing a foundation for later eta production measurements in nuclei, and for studying baryon resonances which couple to etas. E93-033 will search for firmly predicted yet undiscovered baryon states which decay to, for example, $\Delta\pi$ instead of the better-studied Nπ. This experiment will undertake the analysis of $p\pi^+\pi^-$ final states and do the necessary partial wave analysis to extract new intermediate states. E94-015 seeks to measure an amplitude strictly forbidden by the full QCD Lagrangian, but which is present as an "anomaly" in the simplest effective Lagrangian which is solvable. The experiment will actually use the reaction $\gamma p \rightarrow \pi^+\pi^o n$, and hinges on extraction of the t-channel pole term corresponding to the anomalous reaction.

It should be noted that each of the groups involved in these experiments is playing a substantial role in developing the hardware for the CLAS spectrometer or photon tagger.

For several years there has been an understanding within the collaboration that several of the real photon experiments would gather data in parallel. At the present time the plan is for all of these experiments to accumulate data within the same 65 day running period. This concept was endorsed by PAC6. Compromises in running conditions mean that no experiment collects data at an optimal rate, but all participants have so far expressed agreement with the proposed running scenario. This scenario pre-supposes that the trigger for the CLAS will work as advertised, that is, up to a full 1,500/sec single-particle event rate will be recorded with acceptably small deadtime. In other words, the trigger can be "minimum bias," with no on-line selection of rare types of events necessary. Because the tagged photon spectrum goes roughly as 1/E, data taking will be prescaled at the trigger level to suitably even out the recorded rate as a function of energy. The present running scenario is as follows:

Beam endpoint energy: $E_o = 2.4$ GeV 5 days setup, 52 days running

- Liquid hydrogen target, 1.0 gm/cm^2
- Tagging range: 20% to 95% of E_o for 0.48 to 2.28 GeV
- Total tagging rate of 1×10^7 photons/second
- Prescale factors:

  16 - from 0.48 to 0.85 GeV (10% of all tagged photons)

  4 - from 0.85 to 1.40 GeV (26%)

  1 - from 1.40 to 2.28 GeV (64%)
- Trigger: the estimated single-charged particle rate under these running conditions is 360/sec, without correcting for acceptances. The estimated deadtime is then 24%. The total hadronic rate in the spectrometer will be about 3000 /sec.
- Magnetic field setting: 20% of nominal field with negative particles bending out. This configuration maximizes acceptance for low momentum particles, especially negative pions from hyperon decays.

Beam Endpoint energy: 3.2 GeV 1 day setup, 7 days running

- Tagging range: 71% to 95% of E_o for 2.28 to 3.04 GeV
- Total tagging rate of 1×10^7 photons/second
- Prescale factors: unity
- Trigger: One charged particle
- Magnetic field setting: 50% of nominal field with negative particles bending out.

Discussions now underway suggest that this running period may be split over three calendar years. It must be expected that some addition setup time will be needed in each year to reestablish and continue the run from previous years.

BEAM REQUIREMENTS LIST

CEBAF Proposal No.: 89-004, 89-024, 91-008, 93-033, 94-015 (For CEBAF User Liaison Office use only.) Date: 12-94

List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assesment Document (RSAD) calculations that must be performed for each experiment.)

Condition #	Beam Energy (MeV)	Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Target Material Thickness (mg/cm²)
1	2400	0.1	Circular Polarization	LH2	1 gm/cm^2
			(if available)		
2	3200	0.1	Circular Polarization	LH2	1 gm/cm^2
			(if available)		

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. For 1995, E_{Linac} = 800 MeV, i.e., available E_{Beam} are 1600, 2400, 3200, and 4000 MeV. Starting in 1996, in an evolutionary way (and not necessarily in the order given) the following additional values of E_{Linac} will become available: E_{Linac} = 400, 500, 600, 700, 900, 1000, 1100, and 1200 MeV. The sequence and timing of the available resultant energies, E_{Beam}, will be determined by physics priorities and technical capabilities.

HAZARD IDENTIFICATION CHECKLIST

CEBAF Proposal No.: 89-004, 89-024, 91-008, 93-033, 94-015 (For CEBAF User Liaison Office use only.)

Date: 12-94

Check all items for which there is an anticipated need.

Cryogenics X beamline magnets X analysis magnets X target type: LH2 flow rate: _____ capacity: _____	**Electrical Equipment** X cryo/electrical devices ___ capacitor banks X high voltage ___ exposed equipment	**Radioactive/Hazardous Materials** List any radioactive or hazadorous/ toxic materials planned for use: NONE
Pressure Vessels ___ inside diameter ___ operating pressure ___ window material ___ window thickness	**Flammable Gas or Liquids** type: LH2 flow rate: _____ capacity: _____ **Drift Chambers** type: CLAS flow rate: _____ capacity: _____	**Other Target Materials** ___ Beryllium (Be) ___ Lithium (Li) ___ Mercury (Hg) ___ Lead (Pb) ___ Tungsten (W) ___ Uranium (U) ___ Other (list below)
Vacuum Vessels ___ inside diameter ___ operating pressure ___ window material ___ window thickness	**Radioactive Sources** ___ permanent installation ___ temporary use type: _____ strength: _____	**Large Mech. Structure/System** ___ lifting devices ___ motion controllers ___ scaffolding or ___ elevated platforms
Lasers type: _____ wattage: _____ class: _____ Installation: ___ permanent ___ temporary Use: ___ calibration ___ alignment	**Hazardous Materials** ___ cyanide plating materials ___ scintillation oil (from) ___ PCBs ___ methane ___ TMAE ___ TEA ___ photographic developers ___ other (list below)	**General:** Experiment Class: X Base Equipment ___ Temp. Mod. to Base Equip. ___ Permanent Mod. to Base Equipment ___ Major New Apparatus Other: _____